Development Results the Model Distribution of Troughputh in the WiMAX Mesh-Network

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***Abstract*—The frequency resource distribution mathematical model is offered as a problem of subchannels' number balancing between radio channels formed by mesh-stations of the wireless network. The use of the offered model has made it possible to raise efficiency of the wireless mesh-network as a whole and ensure the "bottlenecks" absence.**

***Keywords*—WiMAX, mesh-network, primary and secondary interferences, subchannels distribution.**

I. Introduction

The advent of economically effective wireless mesh networks (WMN), based on the WiMAX (Worldwide Interoperability for Microwave Access) technology [1], modified essentially the process of setting up both wireless access networks and transport radio networks. Among many requirements imposed on the wireless mesh-networks (low cost of devices, low level of energy consumption etc.), the main one is the requirement to provide a high efficiency and quality of service (QoS) of the wireless network as a whole. A high level of efficiency can be provided at the cost of refinements in corresponding network protocols and mechanisms responsible for the accessible network resources distribution. Among resources of such type there are: network traffic (information resource), channel capacities (channel resource), queue (buffer resource) as well as separate frequencies and frequency channels (frequency resource), which is of particular importance for the wireless networks [2, 3].

Analysis of the known solutions has shown that at the moment there is rather a wide spectrum of approaches aimed at increasing efficiency and support of QoS through solution of the frequency resource distribution problems. The disadvantage of setting up the frequency resource distribution problem as a problem of frequency channels consists in the necessity to use, first, several receivers-transmitters to avoid the primary interference in every subscriber station (SS) and, second, sufficiently great number of the frequency channels to avoid secondary interference between the neighboring SS. In this case the use of several receivers-transmitters will raise the complexity and cost of the users' stations and will require additional expenditure of electric energy. On the other hand the use of the sufficiently great number of the frequency channels is not always accessible due to overload of the frequency range used for the WiMAX technology functioning.

To eliminate the disadvantages inherent in solution of the frequency channels distribution problem, the frequency planning problem can be presented in the form of the problem of frequency subchannels distribution in the mesh-networks of the WiMAX technology. On the basis of the performed analysis and the stated requirements [4-11] the model for the single channel subchannels distribution is offered. The offered mathematical model is aimed at increase in the mesh-network efficiency as a whole through balancing the number of subchannels singled out for separate radio channels.

II. Model for Distribution of Subchannels in WMN of WiMAX

The following initial data are supposed to be known in the offered model: N – is the general number of stations in the network (base and users stations); K – is the number of the subchannels being used; M – is the general number of radio channels being formed in the network. By a radio channel is meant a set of two mesh-stations of a wireless network carrying out an information exchange without re-receptions.

With the aim to develop a mathematical model for distribution of subchannels in the WMN let us introduce a number of symbols (tab. 1) making it possible to represent graphically the WMN elements.

The concept of radio channels is introduced into the mathematical model making it possible to perform accounting of the WMN territorial distance in the network. The radio channel matrix is a rectangular one, the number of its lines and columns corresponds to the general number of radio channels M, and it has the form

$$D = \left\| d_{m,s} \right\|, \; (s, m = \overline{1, M}),$$

where $d_{m,s} = \begin{cases} 1, & \text{if the common station participates in formation of the } m\text{-th and } s\text{-th radio channels;} \\ 0, & \text{otherwise} \end{cases}$

TABLE I. EXAMPLE OF SYMBOLS OF MESH-NETWORK ELEMENTS

Symbol	Description
● 1	Base station has the first serial number in the network
○ 4	User's station has the fourth serial number
4 ② 5	Users' stations №4 and №5 form radio channel №2
3-6,11 4 ② 5	Subchannels from the third to the sixth as well as the eleventh subchannels are assigned to radio channel №2

Fig. 1 demonstrates the WMN example with the indication of the stations number ($N=8$), as well as the radio channels being formed with these stations ($M=11$).

The following radio channels matrix corresponds to the mesh-network, shown in fig.1:

$$D = \begin{Vmatrix} 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \end{Vmatrix}.$$

Within the frameworks of the given work the notation $N \mid M \mid K$ will be used with the aim to demonstrate topological and functional parameters of the WMN possible configuration. Thus, the notation of the WMN possible configuration, shown in fig.1, will assume the form $8 \mid 11 \mid 32$.

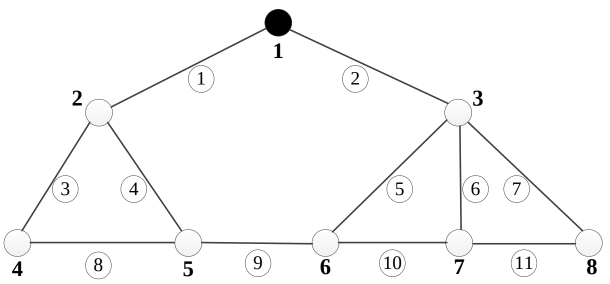


Fig.1. Example of mesh-network with indication of stations $N=8$ and radio channels $M=11$

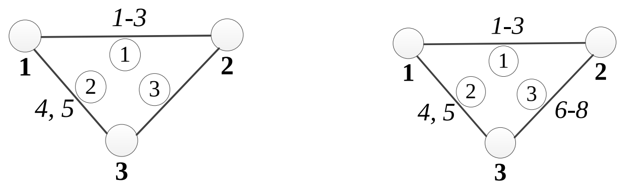
Within the framework of the offered model in the course of solving the subchannels distribution problem, the users' stations of the network should be provided with the Boolean controlling variable calculation

$$x_{m,k} = \begin{cases} 1, & \text{if } k\text{-th subchannel is singled out to } m\text{-th radio channel;} \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

The general number of variables (1), defining the order of subchannels distribution, depends on the number of radio channels being formed in the network, subchannels being used and, respectively, will be defined by the expression $M \times K$. Subchannels assignment to radio channels should be the result of variables (1) calculation. In this connection a number of important conditions-limitations should be met when calculating the sought variables $x_{m,k}$:

1. Condition of every radio channel use (fig. 2):

$$\sum_{k=1}^{K} x_{m,k} \geq 1 \quad (m = \overline{1,M}). \quad (2)$$



a) condition (2) is not met

b) condition (2) is met

Fig.2. Example of checking the condition of every radio channel use

2. Conditions of the primary and secondary interferences prevention (fig. 3 and fig. 4):

$$x_{m,k} + \sum_{s=1}^{M} d_{m,s} x_{s,k} \leq 1, \quad (3)$$

at $k = \overline{1,K}$, $m = \overline{1,M}$, $s \neq m$.

3. Condition of balancing the number of subchannels assigned to every radio channel:

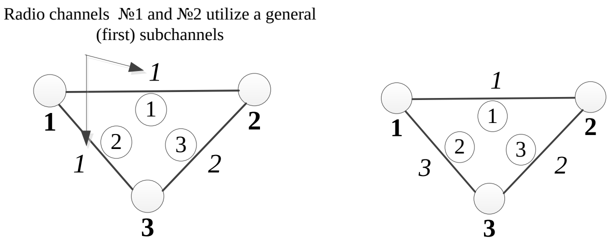
$$\sum_{k=1}^{K} x_{m,k} \geq \chi \quad (m = \overline{1,M}). \quad (4)$$

where in the left-hand part of the inequality the number of subchannets assigned to the m-th radio channel is presented, χ – is the upper dynamically controlled threshold of the subchannels number assigned to the randomly chosen WMN radio channel.

Within the frameworks of the offered mathematical model (1)-(4) the optimization problem solution can be carried out with the following criterion:

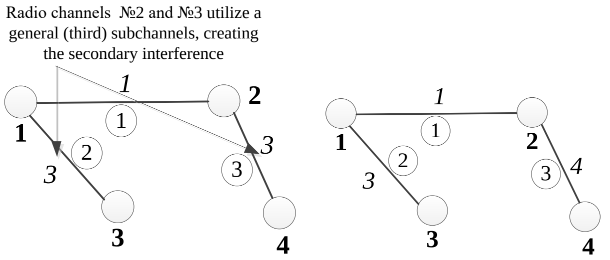
$$\max_{x,\alpha} \chi, \quad (5)$$

directed to the increase in the mesh-network efficiency as a whole through the increase in efficiency of each radio channel. The use of the goal function (5) contributes to creation of the wireless network without “bottlenecks”, i.e. the network where efficiencies of all junctions are balanced ones. The main advantage of the solution obtained with the use of the goal function (5) consists in the possibility of the data packet routing in the mesh network using the metrics of the minimal number of re-receptions, this will significantly simplify the routing functions in the WMN.



a) condition (3) is not met b) condition (3) is met

Fig.3. Example of checking the condition of the primary interference absence



a) condition (3) is not met b) condition (3) is met

Fig.4. Example of checking the condition of the secondary interference absence

The stated problem, from the point of view of physics of the processes taking place in the WMN, relates to the class of the channel resources balancing problems – weighted number of subchannels assigned to the radio channels, and from the point of view of mathematics – it is the problem of the mixed integer linear programming – MILP (Mixed Integer Linear Programming). In the model the sought variables $x_{m,k}$ (1) are Boolean ones, the variable being minimized χ is an integer one and the limitations on the variables being sought bear the linear nature.

III. Conclusion

It was found that one of the main problems in the WMN in the WiMAX technology is the problem of the frequency and time resources distribution between the network stations. In this connection the available approaches to solution of the problem of frequency resource distribution in the WMN in the WiMAX technology were analyzed.

The mathematical model, presented by a number of conditions-limitations, is offered on the basis of the stated requirements put forward to prospective solutions in the field of distribution of the frequency and time resources in the WMN. The model novelty consists in the statement of the frequency resource distribution problem as the problem of balancing the quantity of subchannels between radio channels formed by mesh-stations of the wireless networks, this made it possible to raise the WMN efficiency as a whole and absence of the “bottlenecks” in the mesh-network. In its turn, this, as may be required, will make it possible to perform the data packets routing using metrics of minimal number of re-receptions. Increase in the mesh-network capacity was stipulated by assurance of absence of the primary and secondary interference.

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